# Bridge Resilience Assessment with INSPIRE Data

Yijian (Albert) Zhang, Dr. Reginald DesRoches and Dr. Iris Tien
(Georgia Institute of Technology)

INSPIRE UNIVERSITY TRANSPORTATION CENTER LED BY MISSOURI S&T

Georgia Tech

## INTRODUCTION

In this research, we proposed analytical models validated with numerical results to assess how inspection-collected data on corrosion can be used to update bridge models and predict performance under future events. A detailed investigation of the vulnerability of bridges due to corrosion at both component and global levels. The results show the impact of corrosion-induced degradation on the seismic fragility of reinforced concrete columns under various failure modes, e.g., flexural, shear, and lap-spliced failures. As increasing amounts of data are collected on the states of bridges, the results show how these data can be used to update bridge assessments and prioritize decisions for repair and retrofit to increase component and system performance.

## METHODS

The general framework of this research is summarized into three steps shown below.

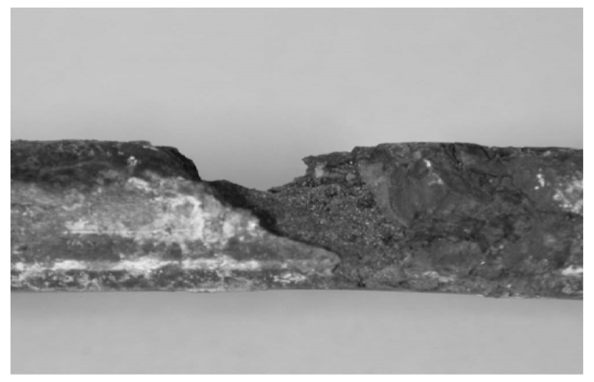
**Step 1** Data Acquisition → **Step 2** Damage Mapping and Finite Element Model Updating → **Step 3** Risk Assessment and Update Fragility Curves

## RESULTS

The Results consist of **three parts**. First two parts introduce the background of modeling three different failure modes of column considering corrosion effect. The last part shows the system fragility assessment of selected bridge type.

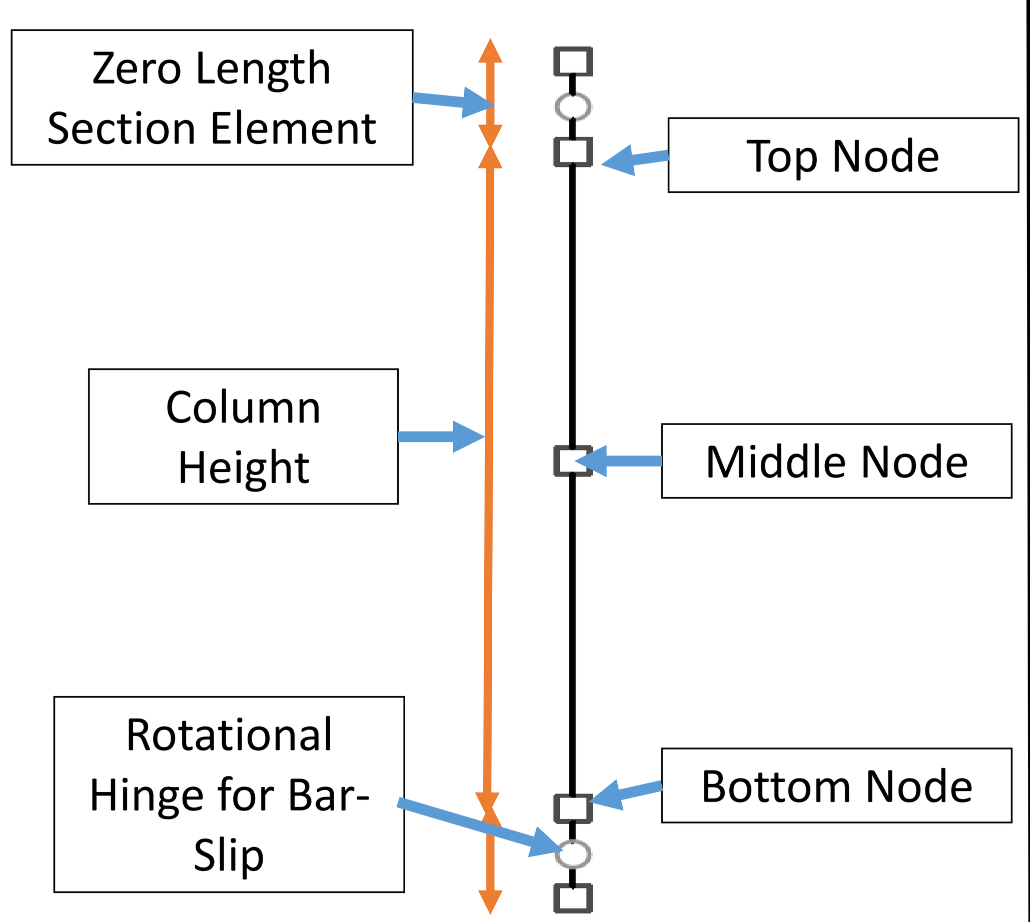
### Part One: Modeling of Flexural Column Considering Corrosion Effect

- **Flexural Failure Mode**
  a) Column fails in bending
  b) Buckling/fracture of longitudinal rebar
- **Mass Loss**
  Reduction of steel bar after removing corrosion products



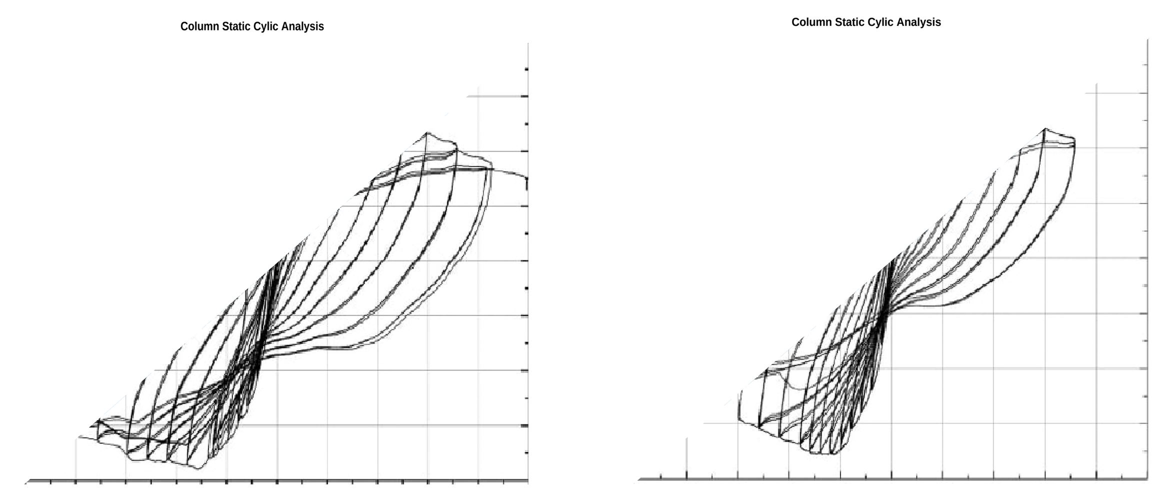
Mass Loss Of Reinforcement (Picture from Bertolini, 2005)

#### Numerical Column Model




Flexure-Critical Column

#### Static Cyclic Test Verification




**Blue**: Numerical Model
**Black**: Experimental Test

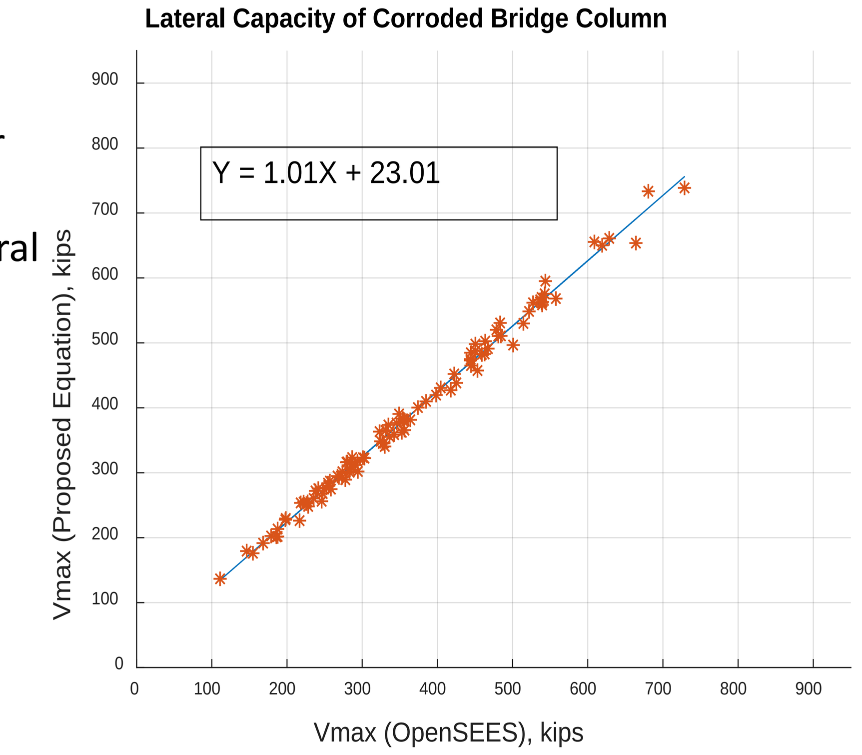
Note:
- C0: 0% Mass Loss
- C10: 10% Mass Loss

#### Proposed Equation of Lateral Capacity of Corroded Flexural Column

$$D_{cor} = \frac{D_o}{10}\sqrt{100-\psi} \qquad A_{s\_cor} = \frac{\pi {D_o}^2}{4}(1-\psi/100) \qquad f_{s\_cor} = f_s(1-\beta\psi)$$

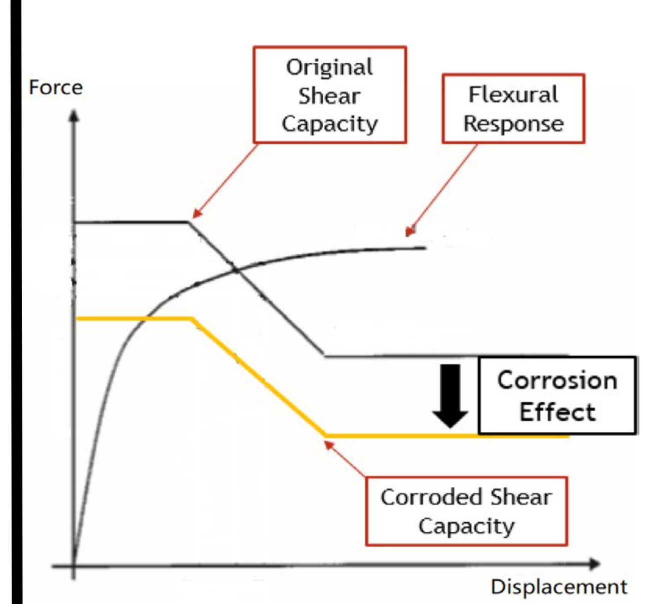
$$V_{\max\_cor} = \frac{0.85 f_c' \overline{A}_c}{L_n} + \frac{\pi {D_o}^2}{4L_n}\sum_{i=1}^{n} f_{pr}(1-\beta\psi)(1-\psi/100)(\frac{h}{2}-d_i')$$

Note:
- $\psi/100$ := longitudinal mass loss ratio
- $\beta$ := pitting coefficient
- $D_o$, $D_{cor}$ := pristine, corroded diameter of bar
- $A_{s\_cor}$ := corroded area of rebar
- $V_{\max\_cor}$ := Lateral capacity of corroded flexural column
- $f_c'$ := compressive strength of concrete
- $\overline{A}_c$ := compressive area of concrete
- $L_n$ := column height
- $f_s$ := yield strength
- $f_{pr}$ := $1.25 f_s$
- $d_i'$ := distance from steel layer to neutral axis
- $n$ := number of steel layer
- $h$ := section height

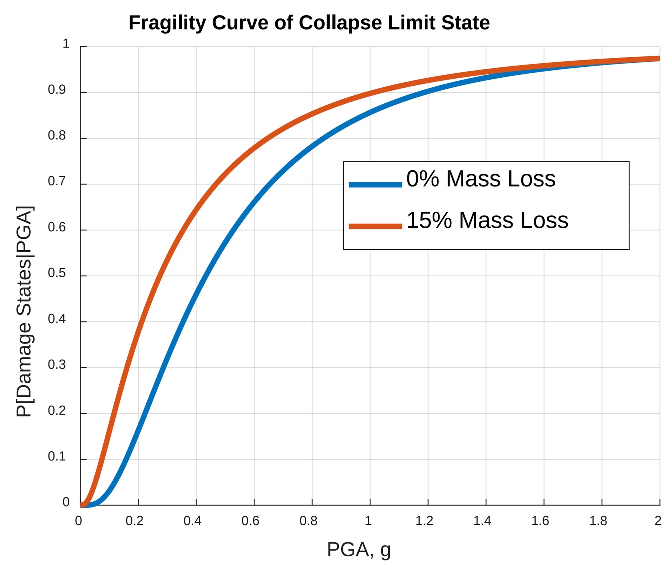



### Part Two: Shear and Lap-Splice Column Considering Corrosion Effect

#### Corrosion Effect on Shear Failure




Corrosion Mechanism



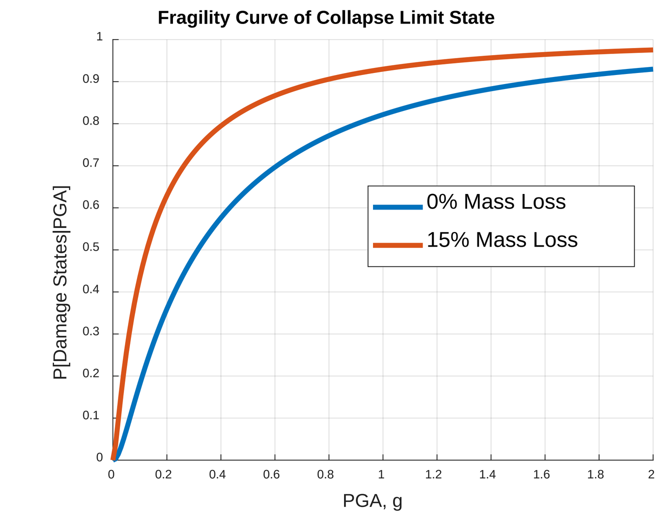

Effect of Mass Loss on Fragility

- Shear capacity is function of mass loss.
- Shear capacity of the column decreases as corrosion product accumulates.

#### Corrosion Effect on Lap-splice Failure

$$f_{s\_cor} = \frac{1.192e^{-0.117\psi}}{\sqrt{1-\frac{\psi}{100}}} f_s$$

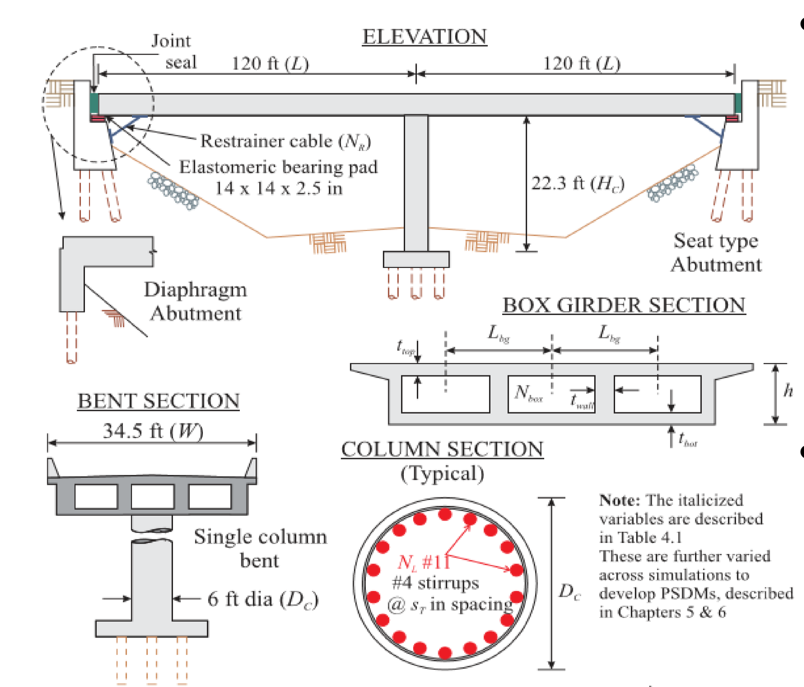
$$f_{r\_cor} = \frac{(1-0.005\psi_t)(1-\frac{\psi_t}{100})}{(1-\frac{\psi}{100})} f_r$$




Effect of Mass Loss on Fragility

Note:
- $\psi_t/100$ := ratio of mass loss of transverse reinforcement
- $f_{s\_cor}$ := corroded yield strength
- $f_{r\_cor}$ := corroded residual strength
- $f_r$ := pristine residual strength

### Part Three: System-Level Fragility Assessment

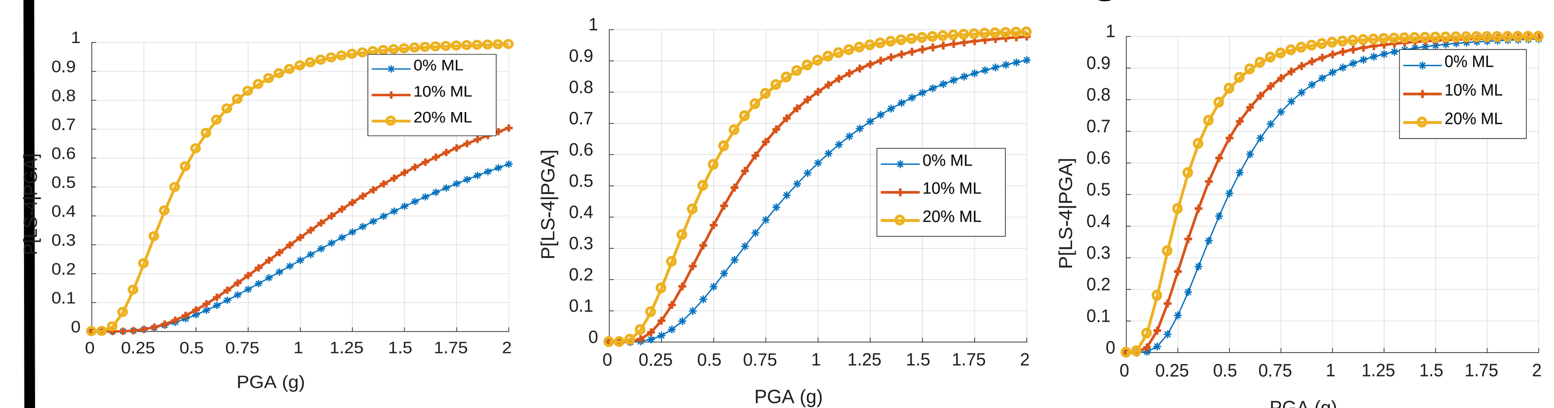



Bridge Details

- The bridge system failure probability is assuming the bridge as a series system.

$$P[System\ Failure] = P\left(\bigcup_{m=1}^{M} m^{th}\ Component\ Failure\right)$$

- The following shows system fragility curves of final limit state (collapse) for each failure type considering both corroded column and corroded bearing.




Flexure-Critical Column | Shear-Critical Column | Lap-Splice Column

## CONCLUSIONS

1. The numerical model is able to capture three different failure modes of bridge column considering corrosion effect.
2. We show the ability to quantify the increase of probability of failure of different bridge systems due to corrosion.

## REFERENCE

Zhang, Y., DesRoches, R., and Tien, I., "Updating Bridge Resilience Assessment Considering Corrosion Inspection Data," ASCE Engineering Mechanics Institute Conference, 2018

## ACKNOWLEDGEMENTS

- Georgia Institute of Technology
- INSPIRE University Transportation Center